

# DETERMINING THE DISSOLUTION RATES OF MINERAL POWDERS IN SIMULATED LUNG FLUID IN ORDER TO BETTER UNDERSTAND THE PERSISTENCE OF LUNAR DUST IN THE HUMAN RESPIRATORY SYSTEM

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NASA and commercial space exploration missions beyond low Earth orbit are likely to become more commonplace going into this century. Travel to other planetary bodies puts future explorers at risk for being exposed to planetary regolith. The Moon's surface is composed of a layer of fine particles that consists of 20% grains that are <20  $\mu\text{m}$  in diameter.<sup>1</sup> Inhalation of such particulates is evidenced to lead to inflammation of respiratory tissues which can result in the development of bronchogenic carcinoma.<sup>2</sup> Apollo astronauts acquired symptoms such as headaches, fever, and nausea which was attributed to the inhalation of lunar dust.<sup>3</sup> Past work included the study of reactive oxygen species (ROS) generated when powdered mineral phases similar to those found in lunar dust were incubated in DI water, which demonstrated that iron-rich silicates generated the most ROS compared to iron-deficient silicates.<sup>4</sup> Exposure to lunar dust is suspected to have negative side effects due to the potential cytotoxic effects associated with dust inhalation.<sup>5</sup> It is important however, to understand how long lunar dust may persist in the human respiratory system. Assessing the dissolution rates of powdered mineral phases in simulated lung fluid (SLF) would give useful information as to how long lunar dust grains would persist in the respiratory system based on their mineralogical composition. The amount of time a 1  $\mu\text{m}$  particle of forsterite takes to dissolve in water is approximately 302 years, versus 5.06 years for enstatite, and 17,000 years for quartz.<sup>6,7,8</sup> We have conducted a set of trial experiments in which batch reactors containing olivine powder (sieved to <63 micron) incubated in SLF and DI water were rotated on an end over end tube rotator for periods of 1 hour, 1 day, 1 week, and 2 weeks to assess the approximate rate of olivine dissolution in these media. Fluid pH was monitored at the beginning and end of each experiment, and was seen to rapidly evolve from pH 5.6 (DI water) and pH 7.4 (SLF) to steady state values of 8-9. Dissolved cation concentrations were measured on an ICP optical emission spectrometer after separating the fluid from the solid particulates by filtration and acidifying the fluid. Initial results indicate that magnesium release from the olivine is an order of magnitude more rapid in

SLF compared to DI water, and rates compare favorably to published values for olivine dissolution. For example, our SLF-based olivine dissolution rate is  $3.12 \times 10^{-9} \text{ mol m}^{-2} \text{ sec}^{-1}$  at pH 8, compared to  $\sim 1 \times 10^{-10} \text{ mol m}^{-2} \text{ sec}^{-1}$  at pH 8 in DI water measured by Pokrovsky and Schott.<sup>9</sup> These trial experiments provided confidence that measurable dissolution rates in SLF can be obtained in reasonable laboratory timescales. We are now conducting follow-on experiments using a flow-through apparatus to measure the dissolution rates of olivine in both SLF and 0.1 M HCl at body temperature (37°C) using reactors modeled after those that were employed by Gainey et al. (2014).<sup>10</sup> Dissolution rates measured in this system will be more robust than those obtained from our batch reactor experiments. This work will further the understanding of lunar dust persistence within the respiratory system.

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